State of California
The Resources Agency
Department of Water Resources
Environmental Services Office

FEATHER RIVER STUDY
CHINOOK SALMON EMIGRATION SURVEY

October – December 1996

November 1999

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Summary

This report presents the results of the second season (October through December 1996) of the Feather River Study salmon emigration survey.

Two rotary screw fish traps (RSTs) were used to collect salmon emigration data from the lower Feather River. One RST (hereafter referred to as the Thermalito RST) was deployed at the downstream end of the low flow channel (approximately river mile 60). A second RST was deployed downstream of Honcut Creek (the lower end of the study area) at approximately river mile (rm) 42, hereafter referred to as the Live Oak RST. The upstream Thermalito RST was deployed at the beginning of October 1996 in an effort to determine whether an RST might capture emigrating steelhead smolts in the fall. The downstream RST at Live Oak was deployed at the beginning of December. Both RSTs were to be operated through the end of June 1997, but they were lost during extreme flood control releases (peak was about 140,000 cfs) which began the week of 29 December 1996. Although the RSTs were recovered, sampling was discontinued for the remainder of the season due to damage to the RSTs and the RST mooring sites, hence the survey produced minimal information.

Fifteen fish species were caught. The Thermalito RST began catching juvenile salmon 15 November 1996. A total of 1,945 juvenile salmon were caught between 15 November and 26 December 1996. Of the total catch, 1,755 salmon were captured in the Thermalito RST and 191 were captured in the Live Oak RST. Salmon size ranged from 27 to 39 mm fork length at Thermalito and from 28 to 39 mm fork length at Live Oak. No steelhead were caught.

Introduction

In 1991 the California Department of Water Resources (DWR), in cooperation with the California Department of Fish and Game (DFG), began the Feather River study to examine the effects of temporary water transfers between the State Water Project and Yuba County Water Agency on chinook salmon and other fish. The initial study sought to determine the effect of flow on fish habitat. Study objectives included the development of a flow model using Instream Flow Incremental Methodology (IFIM) and a temperature model.

In 1995, study was expanded to gather fishery data in support of the Federal Energy Regulatory Commission (FERC) relicensing of the State Water Project's Oroville Complex and to address issues raised by the Central Valley Project Improvement Act's (CVPIA) Anadromous Fish Restoration Program (USFWS 1997). To this end, DWR initiated a number of studies in the lower Feather River consisting of five major elements: (1) chinook salmon spawning; (2) chinook salmon emigration; (3) chinook salmon spawning gravel evaluation; (4) hatchery tagging program; and (5) a Feather River literature database.

One of the primary elements of the Feather River study is the salmon emigration survey. This element examines the timing and magnitude of emigration of naturally produced salmon relative to different physical conditions and spawning activity during the previous fall. Although the main focus is salmon, useful data are also collected on steelhead, splittail, and other fish species.

Emigration is monitored primarily using rotary screw fish traps (RSTs). RSTs are sturdy, relatively easy to move within the stream, relatively easy to operate and maintain, are able to capture fish without harm in fast-moving water, and can sample continuously. Two RSTs are installed, one at the lower end of each of the two study reaches, and operated for approximately six months (mid-December through June). Two RSTs are necessary because flow is more strictly regulated in the low flow channel than in the reach below Thermalito Outlet, and therefore emigration cues and species composition may be different for the two reaches.

The emigration of salmonids and other species has not been monitored in the Feather River since the 1970s (Painter and others 1977). The US Fish and Wildlife Service and the DFG have recently increased their fish monitoring activities (using RSTs and other gear) in the Sacramento River and San Joaquin River systems. This study will make a valuable contribution to the increasing pool of knowledge about fish populations in the Central Valley and provide useful information about fish movement in the Feather River. Other relevant salmon monitoring on the lower Feather River consists of a chinook salmon spawning survey (carcass counts) and an angler survey conducted by the DFG.

The emigration survey objectives aim to achieve the following:

1. Document general salmonid emigration attributes, such as timing and abundance.

2. Investigate the influence of factors thought to initiate emigration, such as flow, turbidity, and water temperature.

3. Develop annual juvenile salmon production indices by relating information on spawning intensity to emigration data. The indices will be used to examine the effects of different physical and biological factors on Feather River salmon production.

Methods

Study Area

The lower Feather River (Figure 1) is located within the Central Valley of California, draining an extensive area of the western slope of the Sierra Nevada. The reach between Oroville Dam and the confluence with the Sacramento River is of low gradient. Above Lake Oroville, the river has three forks, the North Fork, Middle Fork, and South Fork, which converge at the lake. Lake Oroville, created by the completion of Oroville Dam in 1967, has a capacity of approximately 3.5 million acre-feet (maf) of water and is a multi-use reservoir providing flood control, water supply, power generation, and recreation. Flow in the lower Feather River below the reservoir is regulated through releases from Oroville Dam, Thermalito Diversion Dam, and the Thermalito Afterbay Outlet. Under normal operations, the majority of water released from Lake Oroville is diverted at Thermalito Diversion Dam into the Power Canal and Thermalito Forebay (Figure 2). The remainder of the flow, typically 600 cubic feet per second (cfs), flows through the historical river channel, typically referred to as the "low flow channel." Water released from the forebay is used to generate power as it is discharged into Thermalito Afterbay. Water is returned to the Feather River through Thermalito Afterbay Outlet, then flows southward through the lower reach to the confluence with the Sacramento River at Verona. The Feather River study area (see Figure 2) is 23 river miles long and consists of the low flow channel, which extends from the Fish Barrier Dam (rm 67.25) to Thermalito Outlet (rm 59), and a lower reach from Thermalito Outlet to Honcut Creek (rm 44). The confluence with the Yuba River (rm 27.5) is 16.5 river miles further downstream from Honcut Creek. The study is focused on the upper 23 river miles (rm 44 to 67) of the lower river because it is the portion of the river where salmonid spawning occurs. River miles 0 to 44 are comprised mostly of flatwater habitat with substrates consisting mostly of fines.

The Fish Barrier Dam, just downstream of the Thermalito Diversion Dam, is the upper limit for upstream migrating fish. The base of the Fish Barrier Dam is where the fish ladder begins, guiding fish into Feather River Hatchery. The hatchery was built by DWR to mitigate for loss of chinook salmon and steelhead spawning and rearing habitat resulting from construction of Oroville Dam.

Data Collection

The primary sampling devices used for the emigration survey were two eight-foot RSTs. A RST operates in the following manner to capture fish: with the trapping cone lowered into flowing water, water strikes the baffles on the inside of the trapping cone, causing the cone to rotate. Fish enter the upstream end of the rotating trapping cone, become trapped inside the trapping cone, and are carried rearward into a livebox. One RST was placed at the downstream end of the low flow channel at approximately rm 60, just upstream of the Thermalito Outlet (see Figure 2). The other was placed in the lower reach near the town of Live Oak (approximately rm 42) (see Figure 2). Separate RSTs are needed because the operation of the Oroville Complex results in two substantially different flow regimes: flow in the low flow channel is more strictly regulated and is generally relatively low and constant; the lower reach (below Thermalito Outlet), is subject to flow fluctuations and flows usually range from 750 to 40,000+ cfs during emigration. Because the flows can be so different in the two reaches, emigration cues and species composition may differ. The RST sites were selected based on the following criteria for RST installation, operation, and maintenance: (1) suitable depth (greater than six feet at minimum flow); (2) suitable velocity (greater than two feet per second at minimum flow); (3) suitable anchoring point(s); and (4) relatively limited public access.

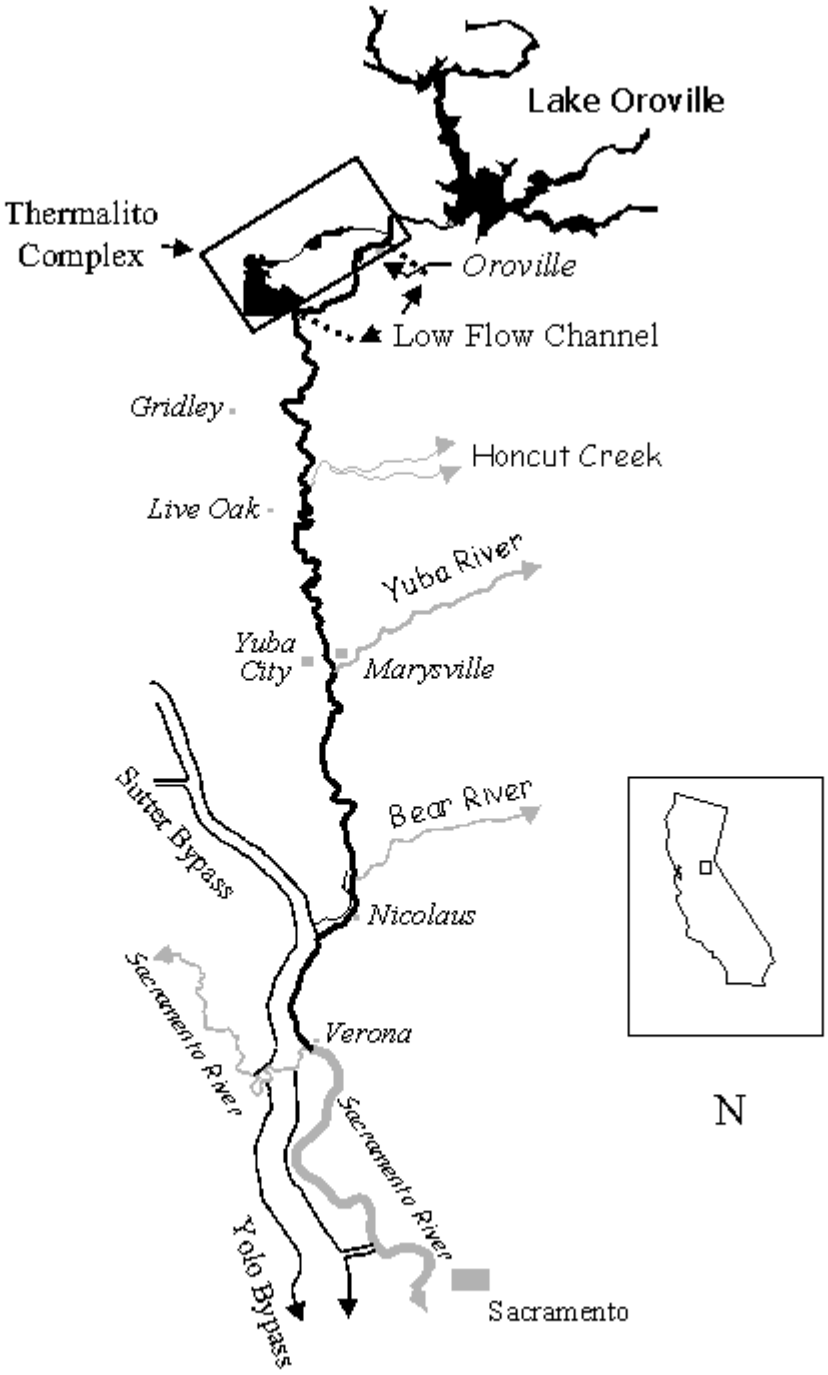


Figure 1 Lower Feather River and associated tributaries between Oroville Dam and the confluence with the Sacramento River

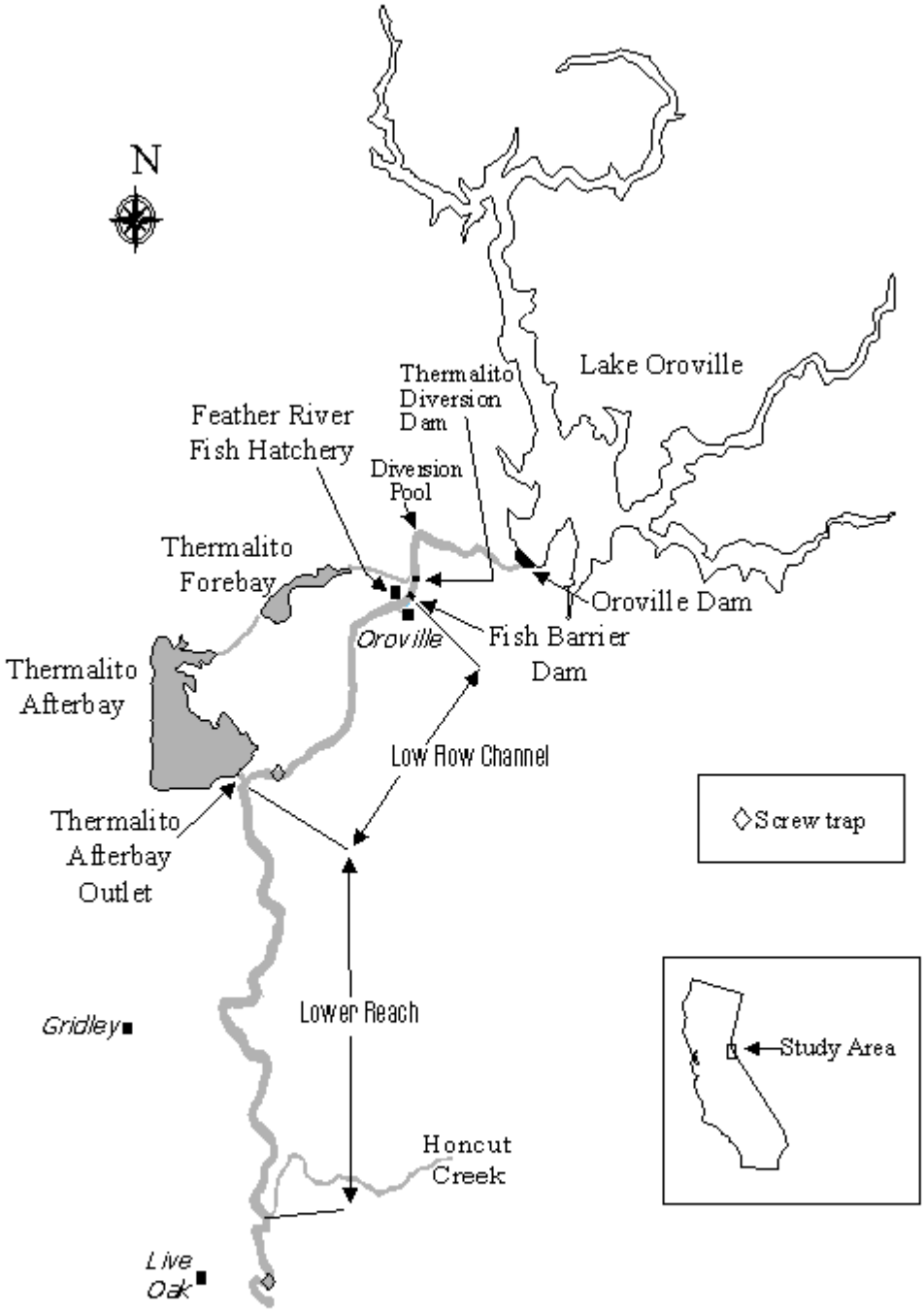


Figure 2 Feather River study area

The Thermalito RST was deployed in early October (2 October 1996) in an effort to determine whether a RST might capture emigrating steelhead smolts in the fall. The Live Oak RST was deployed in early December (2 December 1996). Both RSTs were fished continuously except for a short period when river conditions became unsafe for fishing them. Both RSTs were serviced at least once a day in the morning and more often when the amount of debris warranted it. During servicing, trapped fish were removed from the livebox, identified to species, and counted. Fork length (FL) was measured to the nearest millimeter for up to 50 individuals of each species.

Other data were also collected daily at each RST: water clarity (secchi depth), water temperature, the length of time the RST fished during the sample period (number of hours fished since last service), average trapping cone revolutions per minute, and the total number of trapping cone revolutions during the sampling period. These parameters were selected to increase consistency of this project with other fish monitoring projects occurring in the Sacramento River system. Flow data came from DWR records of releases from Oroville Dam and Thermalito Afterbay Outlet.

Both RSTs were to be operated through the end of June 1997, but were lost during extreme flood control releases (peak was about 140,000 cfs) which began the week of 29 December 1996. Although the RSTs were recovered, sampling was discontinued for the remainder of the season due to damage to the RSTs and the RST mooring sites.

Results

Flows

Flows were mostly 1,600 cfs in the low flow channel for the three months the Thermalito RST fished. This flow level represented an experimental increase over the normal level of 600 cfs in order to test the effects of higher flow on salmon spawning and juvenile rearing. In the lower reach flows ranged from 2,500 to 25,000 cfs for the one month that the Live Oak RST was deployed. There was a minor flood control release in December which resulted in increased flows in both reaches (low flow channel: 5,000 to 10,000 cfs, 11 to 16 December 1996 and lower reach: 10,000 to 25,000 cfs, 11 to 23 December 1996). The Thermalito RST was not fished 11 to 16 December 1996. The Live Oak RST was not fished 11 to 18 December 1996. Both RSTs were stopped fishing when large flood control releases (35,000 cfs in the low flow channel and 50,000 cfs in the lower reach) began 27 December 1996, and the extreme flow event began approximately four days later with flows peaking at approximately 137,000 cfs on 2 January 1997 (Figure 3). Both RSTs were lost in the extreme flood control releases, but were recovered. Damage to the RSTs and mooring sites precluded sampling for the remainder of the season.

Water Temperature and Water Clarity

The following table summarizes water temperature and water clarity readings during the lower Feather River chinook salmon emigration survey from October through December 1996.

	Thermalito RST (02 October - 27 December 1996)	*Live Oak RST (02 - 27 December 1996)*
Water Temperature (°F)	49 - 56	49 - 52.2
Secchi Reading (ft)	3.1 - 8.3	0.9 - 9.8

RST Catch

A total of fifteen species was caught: 12 species at Thermalito; nine species at Live Oak (Table 1). The October through December 1996 survey caught many of the same species caught in the March through June 1996 survey (DWR 1999), plus two additional species: green sunfish (*Lepomis cyanellus*) and black bullhead (*Ameiurus melas*) (Table 2). The top ten species or species groups in highest abundance were as follows (in order of prevalence): chinook salmon (*Onchorhynchus tshawytscha*), juvenile lampreys (ammocetes, most likely Pacific lamprey (*Lampetra tridentata*)), wakasagi (*Hypomesus nipponensis*), bluegill (*Lepomis macrochirus*), prickly sculpin (*Cottus asper*), juvenile centrarchids (non-*Micropterus* sp.), Sacramento sucker (*Catostomus occidentalis*), Pacific lamprey (*Lampetra tridentata*), juvenile cyprinids, and largemouth bass (*Micropterus salmoides*). Overall catch was dominated by chinook salmon (80% of the total catch, both RSTs combined). The Thermalito RST catch consisted of 91% salmon and the Live Oak RST catch consisted of 37% salmon. No steelhead were caught.

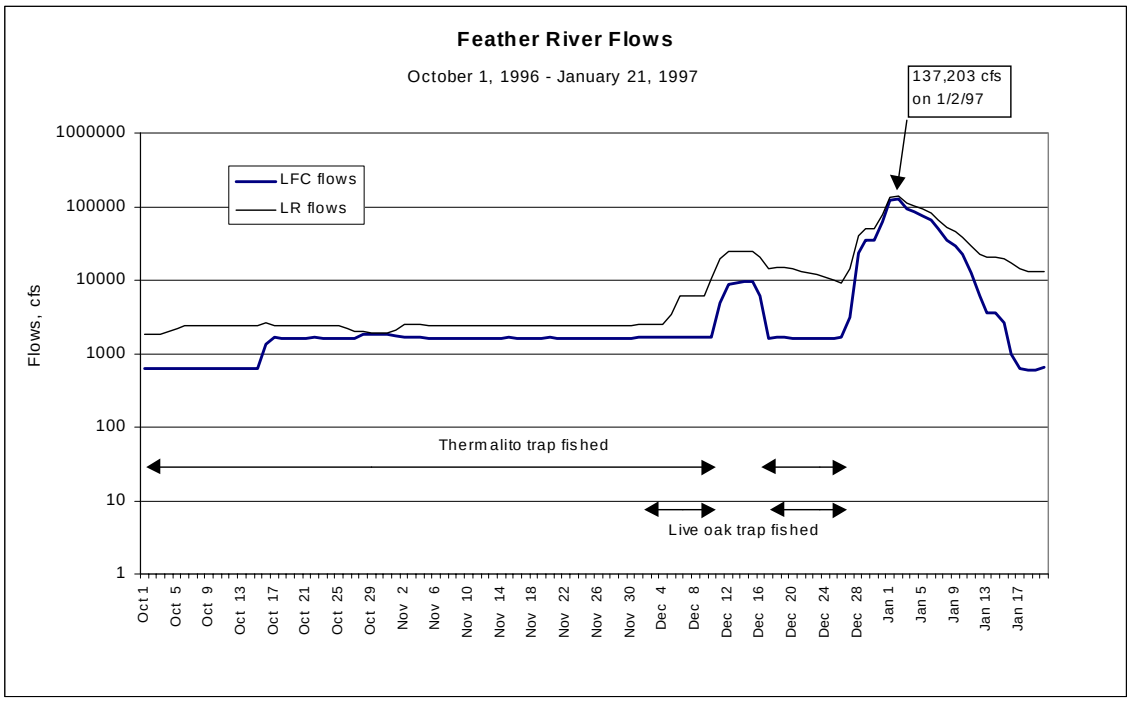


Figure 3 Flows during the lower Feather River chinook salmon emigration survey from October through December 1996

Salmon Emigration

Salmon emigration was first detected in the Thermalito RST on 15 November 1996 (week 46) and in the Live Oak RST on 6 December 1996 (week 49). Thermalito RST salmon catch was 1,755 (Table 3) in 838.9 hours of fishing (2.1 fish/h). Live Oak RST salmon catch was 191 (see Table 3) salmon in 373.4 hours of fishing (0.5 fish/h). Salmon size ranged from 27 to 39 mm FL at Thermalito and from 28 to 39 mm FL at Live Oak (see Table 3). All of the salmon caught were parr. Salmon catch was on the rise when the RSTs were lost (Figure 4).

Table 1 Summary of fish species caught in each RST during the lower Feather River chinook salmon emigration survey from October through December 1996. The RSTs were lost in the January 1997 flood event, which precluded sampling for the remainder of the season.

Species	*Origin*	*Oct*	*Nov*	*Dec*	*Total*
Thermalito Trap (Deployed 1 October 1996)					
juvenile lamprey (ammocete) [a]	Native	9	18	6	33
black bullhead	Introduced	0	0	1	1
bluegill	Introduced	6	0	5	11
chinook salmon	Native	0	8	1747	1755
green sunfish	Introduced	1	1	0	2
mosquitofish	Introduced	2	1	1	4
Pacific lamprey	Native	0	1	9	10
prickly sculpin	Native	2	2	18	22
redear sunfish	Introduced	2	1	0	3
riffle sculpin	Native	0	1	0	1
Sacramento squawfish	Native	2	0	0	2
Sacramento sucker	Native	11	3	2	16
wakasagi	Introduced	10	26	22	58
juvenile cyprinid [a]	Mixed	6	2	0	8
unidentified juvenile [b]	Mixed	2	0	0	2
Total					1928
Live Oak Trap (Deployed 1 December 1996)					
juvenile centrarchid (non-*Micropterus* sp.) [a]	Introduced			19	19
juvenile lamprey (ammocete) [a]	Native			253	253
bluegill	Introduced			21	21
chinook salmon	Native			191	191
largemouth bass	Introduced			7	7
Pacific lamprey	Native			3	3
prickly sculpin	Native			1	1
Sacramento squawfish	Native			4	4
threadfin shad	Introduced			2	2
wakasagi	Introduced			10	10
warmouth	Introduced			1	1
Total					512

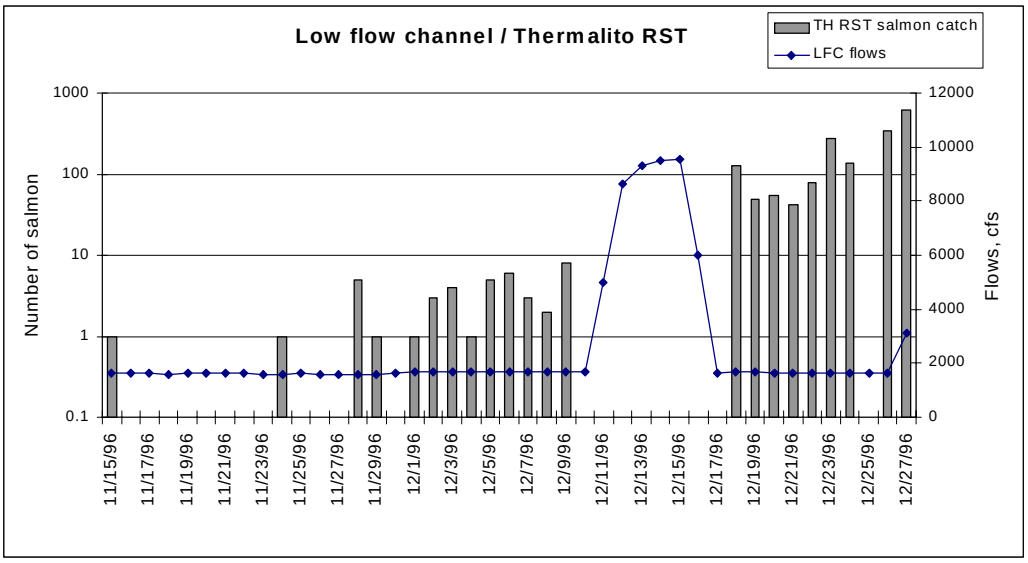
[a] Individuals not identified to species (usually identified to genus or family).
[b] small (<45 mm, often larval-sized) fish that could not be identified in the field.

Table 2 Summary of RST catch during the first two seasons of the lower Feather River chinook salmon emigration study

Species or Groups	*Origin*	*1995 - 1996 (04 Mar - 30 Jun)*	*1996 - 1997 (02 Oct - 27 Dec 1996)*
American shad	Introduced	✓	
bluegill	Introduced	✓	✓
black bullhead	Introduced		✓
brown bullhead	Introduced	✓	
carp	Introduced	✓	
chinook salmon	Native	✓	✓
golden shiner	Introduced	✓	
green sunfish	Introduced		✓
hardhead	Native	✓	
hitch	Native	✓	
largemouth bass	Introduced	✓	✓
mosquitofish	Introduced	✓	✓
Pacific lamprey	Native	✓	✓
prickly sculpin	Native	✓	✓
redear sunfish	Introduced	✓	✓
riffle sculpin	Native		✓
river lamprey	Native	✓	
Sacramento splittail	Native	✓	
Sacramento sucker	Native	✓	✓
Sacramento squawfish	Native	✓	✓
smallmouth bass	Introduced	✓	
steelhead (young-of-the-year)	Native	✓	
steelhead (yearling)	Native	✓	
striped bass	Introduced	✓	
threadfin shad	Introduced	✓	✓
tule perch	Native	✓	
wakasagi	Introduced	✓	✓
warmouth	Introduced	✓	✓
juvenile bass (*Micropterus* sp.)	Introduced	✓	
juvenile lamprey (ammocete)	Native	✓	✓
juvenile cyprinid	Mixed	✓	✓
juvenile centrarchid (non-*Micropterus* sp.)	Introduced	✓	✓
unidentified juvenile	Mixed	✓	✓
Total Number of Species		24	15
Total Number of Native Species		11	6
Total Number of Introduced Species		13	9

Table 3 Summary of chinook salmon catch statistics for the lower Feather River chinook salmon emigration survey from October through December 1996

			Size Statistics (FL in mm)			
Week	*Date*	*Total*	*Mean*	*Minimum*	*Maximum*	*Standard Deviation*
Thermalito Trap (Deployed 2 October 1996)						
40	29 Sep - 05 Oct	0	0	0	0	0
41	06 - 12 Oct	0	0	0	0	0
42	13 - 19 Oct	0	0	0	0	0
43	20 - 26 Oct	0	0	0	0	0
44	27 Oct - 02 Nov	0	0	0	0	0
45	03 - 09 Nov	0	0	0	0	0
46	10 - 16 Nov	1	31	0	0	0
47	17 - 23 Nov	0	0	0	0	0
48	24 - 30 Nov	7	32.1	27	38	3.58
49	01 - 07Dec	20	32.9	29	38	2.83
50	08 - 14 Dec	13	32.4	29	36	2.10
51	15 - 21 Dec	274	34.4	30	39	1.79
52	22 - 28 Dec	1440	33.9	29	38	1.85
Total or Average		1755	33.1	28.8	37.8	2.43
Size Range (mm)				27 - 39		
Live Oak Trap (Deployed 2 December 1996)						
49	01 - 07 Dec	2	35.5	35	36	0.71
50	08 - 14 Dec	5	31.2	30	32	0.84
51	15 - 21 Dec	23	34.7	30	38	2.18
52	22 - 28 Dec	161	34.7	28	38	2.06
Total or Average		191	34.0	31	36	1.45
Size Range (mm)				28 - 38		



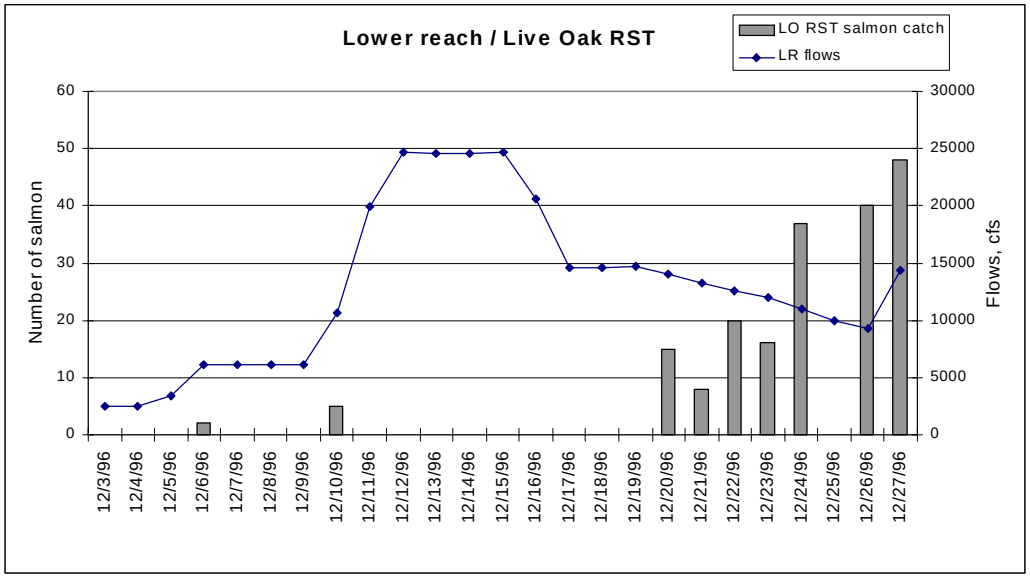


Figure 4 Daily chinook salmon catch distribution and flows during the lower Feather River chinook salmon emigration survey from October through December 1996. The Thermalito RST was not fished from 11 to 16 December 1996 due to high flows. The Live Oak RST was not fished from 11 to 18 December 1996 due to high flows and was fished (but not serviced) on 25 December 1996.

Discussion

The overall survey objectives (see page 3) could not be met for the 1996-1997 sampling season due to the limited amount of data collected; however, some of the findings are discussed here.

RST Catch and Species Composition

The October through December 1996 survey caught many of the same species as the March through June 1996 emigration survey, indicating that the species composition in the fall is similar to species composition in the spring.

Salmonid Emigration

The Thermalito RST detected the start of the emigration period in mid-November (15 November 1996). If this is consistent from year to year, perhaps the emigration survey should be started in November rather than December or January. Unfortunately, none of the previous emigration surveys (Painter and others 1977; Warner 1955) sampled in the fall so there are no historical data to make comparisons of when (in other words, how early) emigration begins.

The start of emigration does not appear to be correlated with water temperature or water clarity. Water temperature at the Thermalito RST ranged from 49 to 54 °F from 15 October to the end of December. There were no changes in water temperature that may have influenced emigration. Water clarity in the low flow channel remained approximately 6.7 feet (secchi disk depth) from the time the Thermalito RST was deployed to the end of December when heavy rains started, so there was no apparent relationship between water clarity and emigration in the low flow channel. There did not appear to be any correlation between water clarity and the start of emigration in the lower reach (r^2 = -0.33).

Flows in the low flow channel were constant (1,600 cfs) except for the seven-day flood control release (11 to 16 December, about 9,500 cfs). Because the Thermalito RST was not fished during the flood control release, there are no fish data to use to determine whether the increased low flow channel flows influenced low flow channel emigration; however, the increase in salmon catch after the higher flows suggests that the higher flows did have some influence on emigration. Similarly, it appeared that flows may have affected emigration at the Live Oak RST. When flows increased from 2,500 cfs to 6,000 cfs in the lower reach, the Live Oak RST began to catch salmon (6 December 1996). When flows were increased further to 20,000 to 25,000 cfs (11 to 18 December 1996) the Live Oak RST was not fished, but once the RST began fishing again (19 December) there was a noticeable increase in salmon catch. Correlation coefficients were 0.8 for the Thermalito RST and 0.7 for the Live Oak RST indicating that there was a relationship between flows and emigration. However, it is difficult to determine whether the increase in RST catch was the result of the increase in flows causing an increase in emigration or if it was due to an increase in the number of fish emerging from the gravel.

RST efficiency was not evaluated. The RSTs were lost before salmon catches were large enough to provide fish for use in efficiency evaluations.

Of particular interest was whether the downstream migration of steelhead yearlings could be detected. The Thermalito RST did not capture any emigrating steelhead for the following likely reasons: (1) the low abundance of juvenile steelhead in the Feather River; (2) steelhead had already emigrated from the low flow channel when the RST was deployed; and (3) steelhead emigrate at a relatively large size, mostly as two- and three-year-old fish (Hallock and others 1961) and their larger size enables them to avoid the RSTs (Thedinga and others 1994). Fishing the RST in August or September might provide more information about emigration of steelhead.

January 1997 Flood Event

It was unfortunate that RST sampling could not be continued after the flood event. The RST's would have provided a way to evaluate the effects of the flood event on juvenile salmonids. The event struck when most of the salmon eggs were still in the gravel and steelhead spawning was still underway. It is probable that the large flows caused riverbed scouring which resulted in loss of salmonid eggs and juveniles in the gravel and flushed juveniles out of the river before they were ready to leave. A temporary river channel was created in the Oroville Wildlife Area (OWA) when a levee broke just upstream of rm 60. When the river receded out of the OWA, there was high potential for stranding and loss of salmonids and other fish species throughout the OWA, which was almost entirely flooded during the event. The levee break at rm 20.5 (near the town of Arboga) also could have contributed to a large loss of fish. There was probably substantial stranding on the floodplain areas of the entire river when the high flows subsided. It will be interesting to examine whether spawning estimates are relatively low three to five years after the flood event.

Acknowledgments

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The Environmental Services Office gratefully acknowledges the Oroville Field Division and the Oroville Mobile Equipment Shop personnel who assisted the Feather River study.

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